ADMITTANCE AND TRANSFER FUNCTION OF A MULTIMESH RESISTANCE-CAPACITANCE FILTER NETWORK*

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ABSTRACT. The impedance function of an n-mesh RC filter network is expressed in the form of a recurring continued fraction. Hindenberg's rule for writing a continuant of the n-th order as an integral function of the n-th degree of its constituents is adopted to experss the above continued fraction as a quotient of two polynomials. The admittance function which is the reciprocal of the impedance function, is then expressed in a very elegant form. The transfer function of the network is then exactly evaluated. In a similar way, the admittance and transfer functions of an n-mesh CR filter network are derived.

INTRODUCTION

Recently Tschudi (1950) has shown that for an n-mesh RC filter network (figure 1) the transfer and admittance fuctions are given by the expressions as follows :

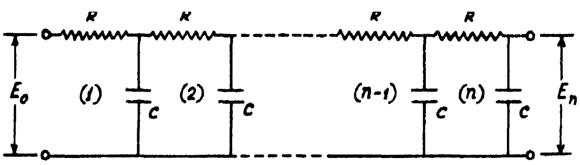

FIG. 1

Transfer function

$$F_n(p) = \left(\frac{E_n}{E_0} \right)_n$$

$$\overline{1 + a_1 Tp + a_2 \cdot T^2 p^2 + \ldots + a_{n-1} T^{n-1} p^{n-1} + T^n p^n} \qquad \ldots \quad (1)$$

and

Admittance function

$$G_n(p) = \frac{Cp[n + b_1 Tp + b_2 T^2 p^2 + \ldots + b_{n-1} T^{n-1} p^{n-1}]}{[1 + a_1 Tp + a_2 T^2 p^2 + \ldots + a_n T^n p^n]} \qquad (2)$$

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where $T = RC$, $p = j\omega$ and $a_1, a_2 \ldots\ldots a_n$ and $b_1, b_2, \ldots b_{n-1}$ are constants given by

$$a_m = \frac{(n+m)\,!}{(n-m)\,!\,(2m)\,!} \tag{3}$$

and

$$b_m = \frac{(n+m)\,!}{(n-m-1)\,!\,(2m+1)\,!} \tag{4}$$

Tschudi has, first of all, assumed the general values of the coefficients a_m and b_m and then proved by the method of induction that his assumptions are correct.

Storch (1951) has applied the junction law of currents to the above circuit (figure 1) to find out a recursion process which gives the complete solution. He has also obtained an alternate solution of the problem in terms of the image parameters θ and Z_0 of a single T-section with a resistor $R/2$ in each series arm and a capacitor C in each shunt arm. The expressions obtained by him are

$$F_n(p) = \left(\frac{E_n}{E_0}\right)_n = \frac{\sinh\,(n+1)\theta}{\sinh\,\theta} - \frac{\sinh\,n\theta}{\sinh\,\theta} \quad \ldots \tag{5}$$

and

$$G_n(p) = \frac{Cp\sinh\,n\theta}{\sinh\,(n+1)\,\theta - \sinh\,n\theta} \quad \ldots \tag{6}$$

where

$$\cosh\,\theta = 1 + pT \quad \ldots \tag{7}$$

This paper deals with the problem with a direct mode of attack with the help of the theory of continued fractions. It will be shown that the admittance and transfer functions for an n-mesh RC filter network can be written in the form of recurring continued fractions. Hindenburg's rule can be applied to write a continuant of the n-th order as an integral function of the n-th degree of its constituents. This rule will be applied to express the recurring continued fractions that we shall obtain, in the form of a quotient of two power series.

The simple process of expressing a recurring continued fraction as a quotient of two polynomials can be applied to any multimesh two element network problem. As an example, the expressions for the admittance and transfer functions of an n-mesh CR network have been derived.

CONTINUED FRACTIONS AND HINDENBURG'S RULE

Let $u_n = p_n/q_n$ be the n-th convergent of the continued fraction

$$P = a_1 + \cfrac{b_2}{a_2 + \cfrac{b_3}{a_3 + \ddots}} \quad \ldots \tag{8}$$

which is generally written as

$$P=a_1+\frac{b_2}{a_2+}\cdot\frac{b_3}{a_3+}\cdot\frac{b_4}{a_4+} \qquad \dots (9)$$

p_n and q_n are determined by the equations

$$\left.\begin{aligned} p_n&=a_n p_{n-1}+b_n p_{n-2}\\ q_n&=a_n q_{n-1}+b_n q_{n-2}\end{aligned}\right\} \qquad \dots (10)$$

with the initial values

$$p_0=1,\ q_0=0$$
$$p_1=a_1,\ q_1=1$$

It is evident, therefore, that q_n is the same function of $a_2, a_3 .. a_n$; b_3 b_4, ...b_n, as p_n is of $a_1, a_2, ...a_n$; $b_2, b_3 ....b_n$.

The function p_n is denoted by

$$p_n=K\begin{pmatrix} & b_2,\ldots\ldots b_n\\ a_1, & a_2,\ldots\ldots a_n\end{pmatrix} \qquad \dots (11)$$

and is called a continuant of the n-th order whose denominators are $a_1, a_2, ...a_n$ and whose numerators are $b_2, ...b_n$.

So

$$q_n=K\begin{pmatrix} & b_3,\ldots\ldots b_n\\ a_2, & a_3,\ldots\ldots a_n\end{pmatrix} \qquad \dots (12)$$

It is convenient to abbreviate both

$$K\begin{pmatrix} & b_2,\ldots\ldots b_n\\ a_1, & a_2,\ldots\ldots a_n\end{pmatrix}$$

and

$$K\,(a_1,\ a_2, \ldots\ldots a_n)$$

into $K(1,n)$. In this notation we have if $r<s$,

$$K(r,\ s)=K\begin{pmatrix} & b_{r+1},\ldots\ldots b_s\\ a_r, & a_{r+1},\ldots\ldots a_s\end{pmatrix} \qquad \dots (13)$$

and

$$K(s,\ r)=K\begin{pmatrix} & b_s,\ \ldots\ldots b_r\\ a_s, & a_{s-1},\ldots\ldots a_r\end{pmatrix} \qquad \dots (14)$$

In particular, $\qquad K(r,\ r)=a_r$

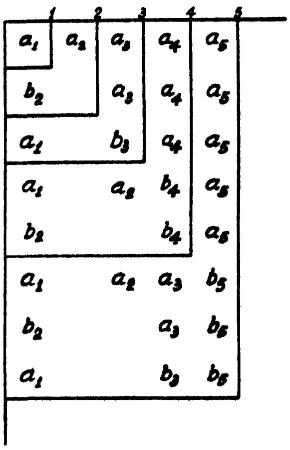
and $\qquad p_1=K(1,\ 1)=a_1$

From equation (10), we have

$$\left.\begin{aligned} &K(r,\ s)=a_s\ K(r,\ s-1)+b_s\ K(r,\ s-2)\\ &K(r,\ s-1)=a_{s-1}\ K(r,\ s-2)+b_{s-1}\ K(r,s-3)\\ &\ldots\quad\ldots\quad\ldots\quad\ldots\quad\ldots\\ &K(r,\ r+1)=a_{r+1}\ K(r,\ r)+b_{r+1}\ K(\quad)\\ &K(r,\ r)=a_r\\ &K(\quad)=1\end{aligned}\right\} \qquad \dots (15)$$

where $K(\quad)$ stands either for unity or for a constituent of that continuent for which the system of numerators and denominators under consideration furnishes no constituents.

Hindenburg's rule is a convenient tool for writing down the terms of a series of continuants, say $K(1,1)$, $K(1,2)$, $K(1,3)$.... This rule is given below



The rule for placing $a_1, a_2, \ldots$ and $b_2, b_3, \ldots$ in the separate rectangles is evident from the scheme given above.

The row in the rectangle 1,1 gives the first term $K(1,1)=a_1$. The rows in the rectangle 2,2 give the products in $K(1,2)$ which is $a_1a_2+b_2$. All the rows enclosed in 3,3 give the products in $K(1,3)$ namely, $a_1a_2a_3+b_2a_3+a_1b_3$.

The process is thus continued. It is nothing but a graphic representation of the recurrence formula

$$K(1,n)=a_nK(1,n-1)+b_{n-1}K(1,n-2) \tag{16}$$

Hindenburg's scheme leads us to Euler's rule for writing down all the terms of a continuant of the n-th order :

The first term is $a_1a_2a_3\ldots a_{n-1}a_n$. To get the rest, one or more pairs of consecutive a's will be omitted from this product in every possible way ; the second a of each pair will be replaced by one b of the same order.

APPLICATION OF EULER'S RULE TO A SIMPLE CONTINUED FRACTION:

Let us consider the simple continued fraction

$$a_1+\frac{1}{a_2+}\,\frac{1}{a_3+}\cdots\cdots\frac{1}{a_n+}\cdots\cdots$$

in which $\quad a_1=a_3=a_5=\ldots\ldots=1$

and $\quad a_2=a_4=a_6=\ldots\ldots=a$

It will be assumed that the continued fraction is of $2n$-th order. So the continued fraction which we shall consider, is

$$1+\frac{1}{a+}\,\frac{1}{1+}\,\frac{1}{a+}\cdots\frac{1}{a} \tag{17}$$

Now the problem is to find out $K(1,2n)$. The first term is

$$1.a.1.a.1.a\ldots\ldots\text{to } 2n \text{ factors}$$
$$=a^n \tag{18}$$

The pairs of consecutive a's are formed and written below :

$$1a,\ a1,\ 1a, \ldots \ldots \text{to } (2n-1) \text{ terms.} \qquad \ldots (19)$$

Let us omit from the product (18) in every possible way r pairs of (19) and replace the second factor of each pair by one b of the same order.

Since, $$b_2 = b_3 = \ldots\ldots = b_{2n} = 1$$

the above replacement procedure will do nothing but multiply the remaining terms in (18) by unity.

So, if r pairs of (19) are removed from (18), the remaining factors in (18) will form a term a^{n-r} The coefficient of a^{n-r} will be the number of the possible ways in which r pairs of (19) may be removed. Now it is evident from (18) and (19) that if $1a$ is removed, the next term $a1$ cannot be taken, *i.e.*, two consecutive pairs of (19) cannot be omitted simultaneously. So the coefficient of a^{n-r} is the total number of combination of $(2n-1)$ terms in (19) taken r at a time so that no two consecutive terms are taken simultaneously. This number is equal to ${}^{2n-r}C_r$.

So, omitting r pairs of (19) from (18) in every possible way we obtain the term

$${}^{2n-r}C_r a^{n-r}. \qquad \ldots (20)$$

Substituting $r = 1, 2, \ldots n$ in (20) we get all the terms of the continuant $K(1,2n)$ of $2n$-th order as given below :

$$K(1,2n) = a_n + t_1 a^{n-1} + \ldots + t_r a^{n-r} + \ldots + t_n \qquad \ldots (21)$$

where $$\left.\begin{aligned} t_r &= {}^{2n-r}C_r \\ t_n &= 1 \end{aligned}\right\} \qquad \ldots (22)$$

Thus, $p_{2n} = k(1,2n)$ has been obtained. It is evident from equation (17) that q_{2n} is the $(2n-1)$-th partial numerator p'_{2n-1} of the continued fraction

$$a + \frac{1}{1+}\ \frac{1}{a+} \ldots\ldots \text{ to } (2n-1) \text{ convergents.} \qquad \ldots (23)$$

In a similar way q_{2n} can now be found

$$q_{2n} = a[a^{n-1} + t'_2 a^{n-2} + \ldots\ldots + t'_r a^{n-r} + \ldots + t'_n] \qquad \ldots (24)$$

where and $$\left.\begin{aligned} t'_r &= {}^{2n-r}C_{r-1} \\ t'_n &= n \end{aligned}\right\} \qquad \ldots (25)$$

So equation (17) can be written in the form

$$1 + \frac{1}{a+}\ \frac{1}{1+}\ \frac{1}{a+} \ldots\ldots \frac{1}{a} \text{ (2n-th convergent)}$$

$$= \frac{[a^n + t_1 a^{n-1} + \ldots + t_r a^{n-r} + \ldots + t_n]}{a[a^{n-1} + t'_2 a^{n-2} + \ldots + t'_r a^{n-r} + \ldots + n]} \qquad \ldots (26)$$

where and $$\left.\begin{aligned} t_r &= {}^{2n-r}C \\ t_r &= {}^{2n-r}C_{r-1} \end{aligned}\right\} \qquad \ldots (27)$$

ADMITTANCE FUNCTION OF RC NETWORK

Consider an n-mesh RC filter network (figure 1). The input impedance function of this network is given by

$$Z_n = R + \frac{1}{Cp+} \frac{}{R+} \frac{}{Cp+} \quad \ldots\text{to } 2n \text{ convergents.} \tag{28}$$

By means of equivalence transformation which consists in multiplying numerators and denominators of successive fractions by numbers different from zero, we can write equation (28) in the form

$$Z_n = R\left[1 + \frac{1}{Tp+}\ \frac{}{1+}\ \frac{}{Tp+} \ldots\text{to } 2n \text{ convergents}\right]. \quad \ldots \tag{29}$$

where

$$\left.\begin{array}{l} T = RC \\ p = j\omega \end{array}\right\}$$

Equation (29) can be identified with equation (17) if we put $Tp=a$. So Z_n can be expressed as

$$Z_n = \frac{R}{Tp} \cdot \frac{[T^n p^n + t_1 T^{n-1} p^{n-1} + \ldots + t_r T^{n-r} p^{n-r} + \ldots + t_n]}{[T^{n-1} p^{n-1} + t'_2 T^{n-2} p^{n-2} + \ldots + t'_r T^{n-r} p^{n-r} + \ldots + n]} \tag{30}$$

where t_r and t'_r are given by equation (27).

Equation (30) can be simplified to

$$Z_n = \frac{1}{Cp} \cdot \frac{[T^n p^n + t_1 T^{n-1} p^{n-1} + \ldots + t_r T^{n-r} p^{n-r} + \ldots + t_n]}{[T^{n-1} p^{n-1} + t_2' T^{n-2} p^{n-2} + \ldots + t_r' T^{n-r} p^{n-r} + \ldots + n]} \tag{31}$$

The admittance function G_n is the reciprocal of the impedance function Z_n and so

$$G_n = Cp \frac{[T^{n-1} p^{n-1} + t_2' T^{n-2} p^{n-2} + \ldots + t_r' T^{n-r} p^{n-r} + \ldots + n]}{[T^n p^n + t_1 T^{n-1} p^{n-1} + \ldots + t_r T^{n-r} p^{n-r} + \ldots + t_n]} \tag{32}$$

Thus the expression for the admittance function G_n has been obtained by a direct method of converting a continued fraction in the form of a fraction in which both the numerator and the denominator are expressed as a power series in Tp.

Arranging the numerator and the denominator in an ascending series in Tp, it can be easily shown that this (equation 32) is identical with that (equation 2) given by Tschudi (1950).

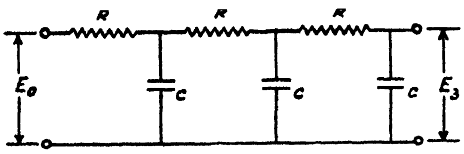


FIG. 2

Example :

Consider the 3-mesh network as shown in figure 2.

In this case $n=3$,

$$t_1={}^5C_1=5$$
$$t_2={}^4C_2=6$$
$$t_3={}^3C_3=1$$
$$t_1'={}^5C_0=1$$
$$t_2'={}^4C_1=4$$
$$t_3'={}^3C_2=3$$

Substituting these values in equation (32), we have

$$G_{T3}=Cp.\frac{T^2p^2+4Tp+3}{T^3p^3+5T^2p^2+6Tp+1}.$$

TRANSFER FUNCTION FOR AN n-MESH RC NETWORK

Let the input voltage of an n-mesh RC filter network (figure 3) be denoted by E_0 and the output voltage by E_n.

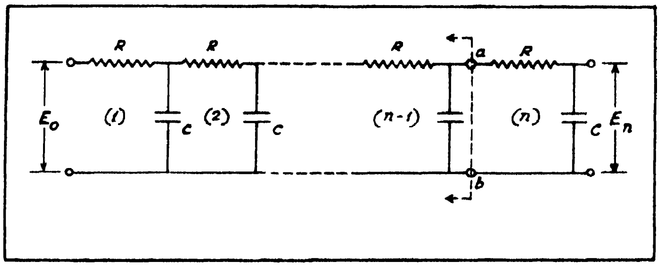


FIG. 3

This circuit is simplified by applying Thevenin's theorem to the portion of the system to the left of the points a, b. The equivalent circuit is as shown in figure 4.

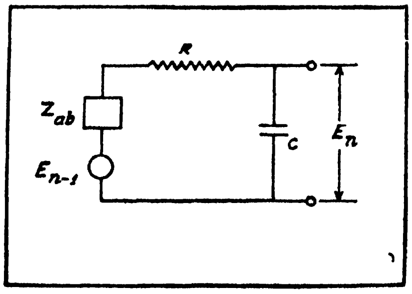


FIG. 4

E_{n-1} = open-circuited voltage measured across $a-b$ and Z_{ab} = impedance of the network looking back into the terminals $a-b$ with all generators replaced by impedances equal to their internal impedances.

Since the only generator present is E_0 and its internal impedance is assumed to be zero, Z_{ab} is the impedance of the network looking back into the terminals $a-b$, when the far end is short-circuited.
From figure. 4,

$$\frac{E_n}{E_{n-1}} = \frac{1}{Cp[Z_{ab}+R+1/Cp]}$$

$$= \frac{1}{Cp[Z_{ab}+R]+1} \quad \dots \quad (33)$$

$$= \frac{Z_n'}{Z_{ab}+R} \quad (34)$$

where Z_n is the impedance of the n-mesh network looking back from the output when the input is short-circuited.
Now,

$$Z_n' = \frac{1}{Cp+}\ \frac{1}{R+}\ \frac{1}{Cp+} \quad \dots\dots \text{to } 2n \text{ convergents}$$

$$= \frac{1}{Cp}\left[\frac{1}{1+}\ \frac{1}{a+}\ \frac{1}{1+}\ \frac{1}{a+} \dots\dots \text{to } 2n \text{ convergents}\right] \dots \quad (35)$$

where $a = RCp = Tp$
with the help of equations (21) and (26), we can write

$$Z_n' = \frac{Tp}{Cp}\left[\frac{a^{n-1}+t_2'a^{n-2}+\dots+t_r'a^{n-r}+\dots+n}{a^n+t_1a^{n-1}+\dots+t_ra^{n-r}+\dots+t_n}\right] \quad \dots \quad (36)$$

where t_r and t_r' are given by equation (27).
Again,

$$R+Z_{ab} = R+\left[\frac{1}{Cp+}\ \frac{1}{R+}\ \frac{1}{Cp+} \dots\dots \text{to } (2n-2) \text{ convergents}\right].$$

$$= R\left[1+\frac{1}{a+}\ \frac{1}{1+}\ \frac{1}{a+} \dots \text{to } (2n-1) \text{ convergents}\right].$$

$$= R.\frac{[a^{n-1}+t_2'a^{n-2}+\dots+t_r'a^{n-r}+\dots+t_n]}{q_{2n-1}} \quad . \quad (37)$$

where q_{2n-1} is the $(2n-1)$ th partial denominator of (17).

From equations (34), (36) and (37), we have

$$\frac{E_n}{E_{n-1}} = \frac{q_{2n-1}}{a^n+t_1a^{n-1}+\dots+t_ra^{n-r}+\dots+t_n} \quad (38)$$

$$= \frac{q_{2n-1}}{p_{2n}} \quad (39)$$

Substituting $n = n-1,\ n-2, \ldots\ldots, 1$, we have,

$$\frac{E_{n-1}}{E_{n-2}} = \frac{q_{2n-3}}{p_{2n-2}}$$

$$\frac{E_1}{E_0} = \frac{q_1}{p_2}$$

From these equations we can easily show that

$$\frac{E_n}{E_0} = \frac{q_{2n-1}}{p_{2n}} \cdot \frac{q_{2n-3}}{p_{2n-2}} \cdot \frac{q_{2n-5}}{p_{2n-4}} \cdots \frac{q_1}{p_2}$$

$$= \frac{q_1}{p_{2n}} \qquad \ldots \quad (40)$$

since for the continued fraction (17) the following identities hold good :

and
$$\left.\begin{array}{l} a p_{2n-1} = q_{2n} \\ p_{2n-2} = q_{2n-1} \end{array}\right\} \qquad \ldots \quad (41)$$

Remembering that $\qquad q_1 = 1,$

Transfer function $F_n(p) = 1/p_{2n}$

$$\overline{a^n + t_1 a^{n-1} + \ldots + t_r a^{n-r} + \ldots t_n} \qquad \ldots \quad (42)$$

where
and
$$\left.\begin{array}{l} t_r = {}^{2n-r}C_r \\ a = Tp \end{array}\right\} \qquad \ldots \quad (43)$$

With the help of this equation we can at once find out the output voltage for an n-mesh network if the input voltage is known.

Example :

Let us calculate the transfer function for a 3-mesh RC filter network (figure 2) Applying equation (41) we can show that

$$\left(\frac{E_3}{E_0}\right) = \frac{1}{T^3 p^3 + 5T^2 p^2 + 6Tp + 1}$$

n-MESH CR NETWORK

FIG. 5

The impedance function of an n-mesh CR network is given by

$$Z_n(CR)=\frac{1}{Cp}+\cfrac{1}{\cfrac{1}{R}+\cfrac{1}{\cfrac{1}{Cp}+\cfrac{1}{\cfrac{1}{R}+}}}\quad \ldots \text{ to } 2n \text{ convergents} \tag{44}$$

By means of equivalence transformation we have

$$Z_n(CE)=\frac{1}{Cp}\quad 1+\frac{1}{RCp+}\quad 1+\frac{1}{RCp+}\ \ldots \text{ to } 2n \text{ convergents} \tag{45}$$

Substituting $\frac{1}{RCp}=b$,

$$Z_n(CR)=\frac{1}{Cp}\quad 1+\frac{1}{b+}\;\frac{1}{1+}\;\frac{1}{b+}\ \ldots \text{ to } 2n \text{ convergents} \tag{46}$$

The continued fraction within the brackets is the same as (17) and we can show with the help of equations (26) and (27),

$$Z_n(CR)=\frac{1}{Cp}\cdot\frac{[1+t_1Tp+\ldots+t_rT^rp^r+\ldots+t_nT^np^n]}{[1+t'_2Tp+\ldots+t'_rT^{r-1}p^{r-1}+\ldots+t'_nT^{n-1}p^{n-1}]} \quad \ldots \tag{47}$$

where t_r and t'_r are given by equations in (27).

So admittance function $G_n(CR)$ is given by

$$G_n(CR)=Cp.\ \frac{1+t'_2Tp+\ldots+t'_nT^{n-1}p^{n-1}}{1+t_1Tp+\ldots+t_nT^np^n} \tag{48}$$

Example :

Let us find out the admittance function for a network in which $n=3$ (figure 6).

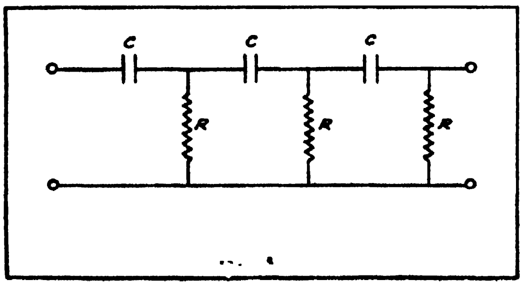


FIG. 6

In this case

$$t_1={}^5c_1=5$$
$$t_2={}^4c_2=6$$
$$t_3={}^3c_3=1$$
$$t'_1={}^5c_0=1$$
$$t'_2={}^4c_1=4$$
$$t'_3={}^3c_2=3$$

Substituting these values in equation (48) we have

$$G_3(CR) = Cp \cdot \frac{1 + 4Tp + 3T^2p^2}{1 + 5Tp + 6T^2p^2 + T^3p^3}$$

where $\left.\begin{array}{l} T = RC \\ p = j\omega \end{array}\right\}$
and

TRANSFER FUNCTION OF THE CR NETWORK

Following a procedure similar to that in the case of an n-mesh RC-network, we can show that the transfer function of an n-mesh CR network is given by

$$\left(\frac{E_n}{E_0}\right) = \frac{(Tp)^n}{[1 + t_1 Tp + \ldots + t_r T^r p^r + \ldots + t_n T^n p^n]} \quad \ldots \quad (49)$$

This expession will be very useful in calculating the responses of the cascaded CR networks to specified signals.

Example :

For the network shown in figure. 6,

$$\left(\frac{E_3}{E_0}\right) = \frac{T^3p^3}{1 + 5Tp + 6T^2p^2 + T^3p^3}.$$

CONCLUSION

The admittance function and transfer function are two very important parameters in network theory and design since they completely determine the response characteristic of a network. The problem to find out expressions for these functions has been tackled from a new and direct angle which will be useful to those who work with network synthesis and design.

The resistance-capacitance filter networks are of common use in electronic circuits. This is why several attempts have been recently made to develop the process of synthesis of RC networks with prescribed response characteristics. The results of this paper will be useful in dealing with such problems.

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REVIEW

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An International Bibliography on Atomic Energy, Volume 2, Scientific Aspects. Supplement No. 1, pp. 350 Atomic Energy Section ; Department of Security Council Affairs, United Nations, New York, 1952. Price $ 3.50, 25/-Stg., 14.00 Swiss frs.

This volume is a supplement of an International Bibliography on Atomic Energy, Volume 2, Scientific Aspects, published in 1951. The volume under reveiw contains a bibliography of the papers published during 1949 and 1950. The investigations have been classified under five broad lines, *viz.*, Fundamental Nuclear Science, Physics and Engineering of Nuclear Reactors, the Biological and Medical Effects of High Energy Radiations, Isotopes in Biology and Medicine and Applications of Radioactive Tracers in Non-biological Sciences and Technology. Each of these lines has been subdivided into different sections, the number of which is thirteen in the case of Fundamental Nuclear Science and smaller in the case of the other four lines. The thirteen sections in the line of Fundamental Nuclear Science are (*A*) The Stable Isotopes of the Elements, (*B*) The Spins, Magnetic Moments and Quadrupole Moments of the Nuclei, (*C*) The Acceleration of Charged Particles, (*D*) Detection of Nuclear Radiations, (*E*) Natural Radioactivity and Radioactivity Geochronology, (*F*) Artificial Disintegration of the Nucleus, (*G*) Artificial Radioactivity, (*H*) Interaction of Neutrons with Matter, (*I*) Fissionof the Atomic Nucleus and Transuranic Elements, (*J*) Passage of Charged Particles or Photons through Matter, Scattering and Pair Production, (*K*) Cosmic Rays, Meson Physics and Astrophysics, (*L*) Theory of Nuclear Structure and (*M*) Books. Some of these sections are again subdivided into sub-sections. There are four sections under the headings, (*A*) Fissionable and Moderator Materials, (*B*) Nuclear Reactors, (*C*) Atomic Energy Establishments and (*D*) Health Protection in the line, The Physics and Engineering of Nuclear Reactors.

The investigations on the Biological and Medical Effects of High Energy Radiations are classified under twelve sections, *viz.*, (*A*) General, (*B*)-(*I*), Effects of High Energy Radiations on Micro-organisms, on Cells, Blood and Tissue, on Genetics and Mutations, on Growth and Development of Organisms, on Organ Systems, on Physiology and on Botany and Agriculture ; (*J*) Medical Aspects of High Energy Radiations, (*K*) Radiation Protection and Dosage Measurements and (*L*) Technical Aspects of Instrumentation.

There are six sections in each of the two lines, Isotopes in Biology and Medicine, and Applications of Radioactive Tracers in Non-biological Sciences and Technology. There are altogether 8,231 references and two Appendices, one being an author index and the other the list of abbreviated names of the journals quoted.

It is needless to mention that this supplementary volume along with the main volume published in 1951 will be immensely helpful to all research workers engaged in the lines of research mentioned above. If the number of pages and quality of the paper used are taken into consideration the price seems to be quite moderate.

S. C. S.

STATISTICAL QUALITY CONTROL
INDIAN STANDARD ISSUED

New Delhi, Oct. 27, 1952.

The Indian Standards Institution has issued the 'Indian Standard Method for Statistical Quality Control During Production by the Use of Control Chart'. It is recommended for use by operatives for maintaining a control procedure in the factory, as well as by teachers and students in any course of training in this field.

It will be recalled that Statistical Quality Control (SQC) Training Courses, arranged under an agreement between the Government of India and the U. N. Technical Assistance Administration, were recently inaugurated in Delhi. This standard has been welcomed both by the visiting professors conducting the course as well as by the trainees, and is being used in their training.

The standard contains two illustrative examples, collected from experience of Indian industry, but otherwise represents an adoption of the American Defence Emergency Standard Zl.3-1942. In its details, the standard describes, step by step, a procedure for setting up a control chart and using it during production to control quality of products.

The control of quality of products to maintain it at a given level reduces the rejection percentage and improves the quality of production without extra capital. The control chart method of controlling quality during production is meant to be an integral part of the production process. This technique, however, does not provide an automatic corrective action in the way mechanical or electrical control systems do. Instead, it gives a warning signal to the operative that he must take, here and now, corrective action on his machine or process to ensure maintenance of quality in further production. Its effectiveness, therefore, depends on the promptness with which the warning is heeded.

The practical value of control chart in SQC technique has been proved by extensive application made during years of actual manufacturing practice. Because of its particular success, its use spread rapidly during the last world war, and it is now being widely utilized in incresing productivity in the U. S. A., U. K., Canada, Australia, Japan, U. S. S. R. and other countries.

In India, attempts to introduce SQC started practically with the establishment in 1944 of a Committee on Statistics, Standards and Quality Control by the Council of Scientific and Industrial Research. On the recommendation of this Committee, courses in SQC began to be given in the Indian Statistical Institute from 1945-46. A big step was taken in 1947 when the Indian Statistical Institute, the Indian Standards Institution and the Indian Science Congress Association invited Dr. Shewhart, the originator of the SQC technique, to visit this country and deliver lectures on the subject. He visited India for four months in 1947-48 and engaged himself in propagating knowledge of SQC through the available channels. At Ahmedabad, the Ahmedabad Textile Industry's Research Association embarked on a scheme to introduce statistical quality control methods in textile mills on a large scale. As a result of their efforts, a number of mills in Ahmedabad have established Statistical Departments.

It is hoped that the present intensive training courses which selected technicians from government departments and industries are undergoing, will lead to greater appreciation and wider application of SQC in India.

The standard is available on sale for Rs. 5/-/- per copy, and may be obtained from the Secretary (Administration), Indian Standards Institution, 19 University Road, Civil Lines, Delhi-8.

GROWING RECOGNITION OF INDIAN STANDARDS
A YEAR OF PROGRESS

Fifth Annual Report of Indian Standards Institution

New Delhi, October 27, 1952

Standardisation made further considerable progress in India during 1951-52. Growing recognition was accorded to Indian standards by industry and Government. The ISI (Certification Marks) Act was passed by Parliament during the year, the Central Government increased its grant to the Institutoin and well over a lakh of copies of Indian standards were sold and distributed, the sales revenue of nearly Rs. 30,000/- representing a 50 per cent increase over last year's figure.

The fifth Annual Report of the Indian Standards Institution, which has just been published, shows that the Institution completed another year of all-round progressive development in which it continued to receive good support both from industry and Government. The membership of the Institution rose from 684 in 1950 to 758 in 1951 with corresponding increase in the subscription collected from Rs. 1,86,500/- to Rs. 2,06,255/-. The number of sectional committees and subcommittees which held 142 meetings against tast year's figure of 100, went up from 264 to 300. The membership of these committees is now about 2,700 and consists of experts drawn from the various technological and industrial spheres, and trade and government departments, spread all over the country. The number of new Indian Standards published by the Institution during 1951-52 was 112. Besides, there were over 500 subjects under study for standardisation, over 100 standards finalised and under print, and over 400 standards in circulation and other stages of preperation at the end of March 1952.

The list of Indian Standards published in the Report shows that nearly two-thirds of them have either been adopted by Government departments, such as the Directorate General of Supplies and Disposals and the Railway

Board, in place of their own specifications or referred to in their purchase specifications.

The important items of the Institution's activities and achievements which the Report records in detail, include the visit of the Prime Minister Shri Jawaharlal Nehru to the Institution in August 1951 and the presentation to him of a National Flag of India prepared in accordance with the Indian Standard. The ISI (Certification Marks) Act, intended to encourage effectively the production of goods in conformity with Indian Standards, was passed by Parliament in March last. The ISI convened a Conference of Directors of Industries of States which recommended to the Central and State Governments that all their purchases be made, as far as possible, according to Indian Standards. A Five-Year Plan for the development of ISI was drawn up and a substantial part of the plan relating to 1952-53 was approved by the Planning Commission, as a result of which the Government increased its grant to the Institution for 1952-53 from 2.2 lakhs to Rs. 4.2 lakhs. With the additional grant, the ISI General Council decided to embark on new projects of setting up the Building Division Cuncil, a Steel Economy section, organising International Electrotechnical Commission work taken over from the Institution of Engineers and the work of laying standards relating to storage and handling of foodgrains.

New Subjects for Standardisation

The Division Councils considered 119 new subjeccts for standardisation during the year under review. Among those which were accepted are sanitary fittings and appliances, ball bearings, safes, fire fighting equipment, hurricane lanterns, bolts, nuts and other fasteners, sports goods, silk waste, towels, duries, blankets, handloom cloth, bone meal, ammonia, raw materials for ceramic industry, safety matches, cashew nut shell liquid and Turkey Red Oil.

For laboratory investigations required in the preparation of Indian Standards the Institution continued to receive active cooperation and assistance from all quarters in the country, and particularly from the laboratories of the Council of Scientific and Industrial Research, the Forest Research Institute, Dehra Dun, the Technical Development Establishment Laboratory (Stores), Kanpur, and the Government Test House, Alipore. The Report gives a list of 46 problems entrusted by the Institution to the organisations and laboratories.

In the international sphere, the ISI is an elected member of the Governing Council of the International Organisation for Standardisation (ISO), and Dr. Lal C. Verman, Director, Indian Standards Institution, is the elected Vice-President of ISO. The Report records the details of cooperation extended by the Indian Standards Institution in international standardisation work.